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# SCH3U-D. Quantities in Chemical Reactions

# -Stoichiometry Concept Presentation-

**Please note that the following components are mixed in with the detailed lesson sequence:**

* Objective
* Lesson
* Assessment and Evaluation
* Misconceptions/difficulties
* Demo
* Practical/societal applications/implications
* Resources (Internet addresses are annotated)

**6 pages, not including title page and Curriculum Expectations**

<http://schools.hwdsb.on.ca/westdale/files/2010/10/Grades-11-and-1210.pdf>

The Ontario Curriculum Grades 11 and 12 Science (2008)

# SCH3U-D. Quantities in Chemical Reactions

Overall Expectations

**D1.** analyse processes in the home, the workplace, and the environmental sector that use chemical quantities and calculations, and assess the importance of quantitative accuracy in industrial chemical processes;

**D2.** investigate quantitative relationships in chemical reactions, and solve related problems;

**D3.** demonstrate an understanding of the mole concept and its significance to the quantitative analysis of chemical reactions.

**D1.1** analyse processes in the home, the workplace, and the environmental sector that involve the use of chemical quantities and calculations (e.g., mixing household cleaning solutions, calculating chemotherapy doses, monitoring pollen counts) [AI, C]

**Sample issue:** Health care professionals are expected to calculate dosages of prescription drugs accurately and safely. This requires precision in applying fractions, decimals, ratios, percentages, and metric conversions. Despite the care taken by health care professionals, improper medication use by patients accounts for about 30% of hospital emergency department visits.

**Sample questions**: Why is baking powder used in cake batter? What happens when too much or too little of that ingredient is used? Why might two people on the same drug regimen not necessarily take the same dosage to treat the same illness? How are carbon dioxide emissions calculated and why are they monitored?

**D1.2** assess, on the basis of research, the importance of quantitative accuracy in industrial chemical processes and the potential impact on the environment if quantitative accuracy is not observed [IP, PR, AI, C]

**Sample issue:** Errors in quantitative accuracy have played a role in many industrial chemical disasters worldwide. Failing to adjust the quantities of chemicals needed to produce different batch sizes of a product have created runaway reactions, resulting in huge explosions. Such industrial accidents can have devastating short and long-term effects on the environment.

**Sample questions:** Why is it important to use the correct salt-sand mix on highways during winter storms? Why is it important to correctly measure the chemicals used in water treatment plants? How might incorrect measurements affect the environment? How and why are environmental contaminants monitored in soil, water, and air around a chemical manufacturing plant?

**D2.1** use appropriate terminology related to quantities in chemical reactions, including, but not limited to: stoichiometry, percentage yield, limiting reagent, mole, and atomic mass [C]

**D2.3** solve problems related to quantities in chemical reactions by performing calculations involving quantities in moles, number of particles, and atomic mass [AI]

**D2.5** calculate the corresponding mass, or quantity in moles or molecules, for any given reactant or product in a balanced chemical equation as well as for any other reactant or product in the chemical reaction [AI]

**D2.6** solve problems related to quantities in chemical reactions by performing calculations involving percentage yield and limiting reagents [AI]

**D2.7** conduct an inquiry to determine the actual yield, theoretical yield, and percentage yield of the products of a chemical reaction.... assess the effectiveness of the procedure, and suggest sources of experimental error [PR, AI]

**D3.4** explain the quantitative relationships expressed in a balanced chemical equation, using appropriate units of measure (e.g., moles, grams, atoms, ions, molecules)

# Stoichiometry Concept Summary

* Stoichiometry describes the quantitative relationships between reactants and products in chemical reactions.
* Mole ratios are used to determine the quantities of one or more substances involved in the reaction. The ratio is found from the coefficients in a balanced chemical equation.

Three basic steps to solving stoichiometry problems:

* Change what you are given into moles.
* Use a mole ratio based on the coefficients in the balanced chemical reaction.
* Change to the units needed for the answer.
* The limiting reactant is consumed completely in a reaction.
* The theoretical yield is the amount of produce that can be formed from a given amount of limiting reactant. The actual yield is the amount of product collected from experimental data.
* Percentage yield is a measure of the efficiency of a reaction. It is the actual yield divided by the theoretical yield, multiplied by 100.

# Lesson sequence

* LESSON 1 Defining Stoichiometry
* LESSON 2 Stoichiometry Calculations
* LESSON 3 Stoichiometry Lab Prep
* LESSON 4 Stoichiometry Lab
* LESSON 5 Solve Stoichiometry Problems
* LESSON 6 Stoichiometry Web Site Review
* LESSON 7 Limiting Reactants and Percent Yield
* LESSON 8 Limiting/Excess Reactants and Percent Yield Lab
* LESSON 9 Reactions with Different Mole Ratios Lab
* LESSON 10 Mixed Reception

# LESSON 1 Defining Stoichiometry

Objectives

* Define stoichiometry.
* Relate and compare stoichiometry to balancing chemical equations.
  + Determine mole ratios using the balanced chemical equation.
  + Solve stoichiometry problems involving mass, volume and particles using the mole diagram.
* Describe, citing examples, how stoichiometry affects personal and public-policy decision-making.

Lesson

* Demo: Reactive substances and correlation with quantities
  + Ask four students to add 5.0ml water to an empty film canister. Have them break up a sodium bicarbonate tablet into four unequal pieces (small, medium, medium-large, large). Students put the piece of sodium bicarbonate on the lid of the film canister. On the teacher’s mark, the students snap on the lid, invert the canister, and back way from the table. The film canisters will pop and launch into the air. Discussion correlates to the size of the tablet.
* Law of Conservation of Matter
  + Write the equation for photosynthesis on the board. Verify that matter and mass are conserved on both sides of the equation.
* PEOE (Predict, Explain, Observe, Explain) Demo: React KMnO4 with NaHSO3
  + Students draw PEOE charts on group whiteboard. Class discussion of how one of the reactants is completely used up and the other is in excess.
* Review rules for balancing equations.
  + Focus lesson lecture. Students take notes. Think-pair-share for group discussion.
* Explain what stoichiometry is and importance
  + Discuss stoichiometry in manufacturing, medicine, geologists (test for CaCO3), space (CO2 scrubbers), air bag inflation, catalytic converters, etc.
  + Real world example with Smores activity.

devacaf.caes.uga.edu/main/lessonPlan/SMoreLP.pdf

Assessment

* Smores lab worksheet to be handed in at the beginning of the next class.
* Assign an STSE project for the stoichiometry unit. Use the curriculum documents in SCH3U D1.1 and D1.2 for topic ideas of how stoichiometry is present in the real world. Students may choose a performance-based assessment from the following website: <http://www.emtech.net/Alternative_Assessment.html>

Misconceptions

* Reagent vs. Reactant terminology
* Law of Conservation of Matter
  + The masses, numbers and types of atoms are the same on both sides of a balanced equation
  + In all types of reactions the atoms involved are rearranged to form new substances

# LESSON 2 Stoichiometry Calculations

Objectives

* List the sequence of steps used in solving stoichiometric problems.
* Solve stoichiometric problems where moles are given.

Lesson

* Focus lesson lecture on mole-mole and mole-mass stoichiometric problems. Students take notes.
* Students work in groups of four to answer the first question. One student from each group is chosen by a lottery system to write the group’s answer on the board. The teacher writes a numerical mark beside each group’s answer and asks the students to make their answers correct. When the questions are all correct, the class moves onto the next question on the sheet.

Assessment

* Remaining questions are for homework. Both worksheets handed in at beginning of the next class period.

<http://www.gpb.org/files/pdfs/gpbclassroom/chemistry/moleMoleProblemsWkst.pdf>

<http://www.gpb.org/files/pdfs/gpbclassroom/chemistry/moleMassProblemsWkst.pdf>

Misconceptions

* One mole of compound always contains one more of each element present in the compound.
  + Review the definition of the mol through discussion and encourage students to watch educational videos on YouTube as a study resource (eg. Khan Academy).
* Substances always react in a 1:1 ratio.
  + Practice finding the molar ratio using a speed round activity. (Each of the students stand, and may only sit once they have answered correctly.)
* Assume the chemical formula represents the mass ratio of individual elements, or the ratio of molar masses of elements.
  + Review the definition of molar mass, having the class collaboratively use calculations involving molar mass.

# LESSON 3 Stoichiometry Lab Prep

Objective

* Using background knowledge on stoichiometry, students design a titration lab experiment to determine molar ratios in a chemical reaction.

Lesson

* Demo: Teacher demo’s a titration using the Virtual Chem Lab website: <http://www.chemcollective.org/vlab/vlab.php>
* Pre-lab prep
  + Arrange students in groups of four.
  + Students will be given the following during the lab: 1 M NaOH, 1 M HCL, 1 M H2SO4, 2 burets, beaker, pH indicator
  + Students design an experiment to calculate the molar ratio of NaOH to HCl, and NaOH to H2SO4.
  + Students verify the procedure with the teacher by the end of class, to ensure they are on the right track. Teacher ensures that lab safety measures are included in the procedure.

Assessment

* Students hand in an individual copy of the procedure at the beginning of the next class period.

Misconceptions

* Lab safety precautions do not need to be written in the lab procedures, because they already know in their minds how to avoid hazards.
  + Reinforce that someone else must be able to read your procedure and it is not ethical to set a person up for running into unexpected safety hazards.

# LESSON 4 Stoichiometry Lab

Objective

* Using background knowledge on stoichiometry, students design a titration lab experiment to calculate molar ratios in a chemical reaction.
* Analyze and summarize lab result in a lab report.

Lesson

* Student groups perform the lab experiments they designed. Instructor answers questions, redirects groups, and ensures lab safety.

Assessment

* Rubric: Observe student performance during lab.
* Lab reports due at the beginning of the next class period. Lab report includes:
  + Introduction, conclusions (balanced equations), procedure, discussion (what might be done differently next time, liked/disliked about the lab).
* Exit ticket: explain how the concepts learned in the previous three lessons will enable them to solve stoichiometric problems. (this will be the topic in the next lesson)

# LESSON 5 Solve Stoichiometry Problems

Objective

* Identify/solve different types of stoichiometric problems.
* Molar volume of gas at STP = 22.4.

Lesson

* Focus lesson lecture each mass-mass, mass-volume, and volume-volume stoichiometric problems. Have students help lead through the sample problems on the board. Students take notes.
* Students complete worksheet working in groups of four. The students can decide how to split up the questions. Each student should have a copy of the answers.

Assessment

* Worksheet to be worked on in class in groups. Each student hands in a copy of the answers two classes from now. The extra day allows students to collaborate with their group members outside of class.

[www.uwsp.edu/education/pcook/unitplans/docs/Stoichiometry.doc](http://www.uwsp.edu/education/pcook/unitplans/docs/Stoichiometry.doc) Pg. 28

* Assign both pre-lab questions for the Stoichiometry Gizmo. These questions must be done before entering the computer lab. Students must bring the Gizmo handout package to the computer lab next class. <http://cs.explorelearning.com/materials/StoichiometrySE.pdf>

Misconceptions

* What the “Molar volume of gas at STP = 22.4 “means; molar volume can be substituted for moles.
  + Watch YouTube of molar volume questions. Have class debate on how to use the molar volume.

# LESSON 6 Stoichiometry Web Site Review

Objective

* Identify/solve different types of stoichiometric problems.
* Evaluate chemistry on the Internet.

Lesson

* Students meet in the computer lab. Have students pair up.
  + Do the Stoichiometry Gizmo on the Internet and fill in the handout. <http://www.explorelearning.com/index.cfm?method=cResource.dspDetail&ResourceID=515>
  + Go to the <http://www.quia.com/jg/4059.html> website. Take turns challenging each other to games, or take turns playing (while helping each other to review).

Assessment

* Students hand in Gizmo worksheet at the end of class.

<http://cs.explorelearning.com/materials/StoichiometrySE.pdf>

* Observe students to make sure they are participating and understanding the concepts of the Quia games.
* Exit ticket on blank lined paper: “What happens if there is an excess amount of one reactant?” Teacher reviews the exit tickets after class and returns them in next class.

# LESSON 7 Limiting Reactants and Percent Yield

Objective

* Determine the limiting reactant of a chemical reaction.
* Calculate the amount of product formed in a chemical reaction, where reactants are not in stoichiometric proportions.
* Calculate percent yield, using theoretical and actual yield.

Lesson

* Give students the stoichiometry flowchart handout.
* Focus lesson lecture on how to identify the limiting reactant in a reaction. Walk students through a sample problem. Students take notes.
* Focus lesson to explain expected yield, actual yield, and how to calculate percent yield. Walk students through a sample problem. Students take notes.
* Show students the following slideshow of real world uses of stoichiometry: <http://www.wiziq.com/tutorial/73848-Chemistry-Stoichiometry-Real-Life-Stoichiometry>
* Jigsaw activity: questions on worksheet.

Assessment

* Students hand in all completed jigsaw questions by the end of class. Students who wish to submit their handouts the following class will receive a maximum mark of a B-.

[www.uwsp.edu/education/pcook/unitplans/docs/Stoichiometry.doc](http://www.uwsp.edu/education/pcook/unitplans/docs/Stoichiometry.doc) Pg. 32

Misconceptions

* When the mass of both reactants is given, students have difficulty recognizing which is limiting and which is in excess. Students will often (a) randomly select one of the given masses as limiting or excess. (b) Not balance the equation. (c) Assume the smaller mass is the limiting reagent.
  + Need to point out that these are not trick questions
  + Stress the common steps for using moles in mole ratios for balanced equations.

# LESSON 8 Limiting/Excess Reactants and Percent Yield Lab

Objective

* Predict how much product will be made.
* Calculate the percent yield.

Lesson

* Students conduct a lab titled Balloon Races.

Assessment

* Students hand in the completed lab report at the beginning of next class.

<http://www.google.ca/url?sa=t&source=web&cd=5&ved=0CDgQFjAE&url=http%3A%2F%2Fdhsacademics.desoto.k12.mo.us%2FLinkClick.aspx%3Ffileticket%3DA0Ie6Oafmok%253D%26tabid%3D457%26mid%3D1486&rct=j&q=When%20all%20of%20the%20liquid%20in%20the%20solution%20has%20boiled%20away%2C%20remove%20the%20flask%20from%20the%20hot%20plate.%20%20The%20powder%20that%20you%20observe%20inside%20is%20the%20product%20of%20the%20reaction%2C%20sodium%20acetate.%20%20&ei=EygxTqLSCMPqgQebyPGBDQ&usg=AFQjCNFnDJGaZHixYohrA5_7hPfoNh4zWA>

# LESSON 9 Reactions with Different Mole Ratios Lab

Objective

* Test combustion properties in mixtures with varied mole ratios. Somewhat of a guided inquiry lab.
* Determine what factors determine the explosiveness of the reaction of hydrogen with oxygen.

Lesson

* Students conduct a lab titled Micro Mole Rockets.

Assessment

* Students hand in the completed lab report at the beginning of next class.

[www.csd509j.net/cvhs/kirscha/MicroMoleRockets%200708.doc](http://www.csd509j.net/cvhs/kirscha/MicroMoleRockets%200708.doc)

# LESSON 10 Mixed Reception

Objective

* Use basic knowledge of formula weight, stoichiometry, the scientific method and limiting reagents to solve a mysterious death.

Lesson

* The class computer (with speakers and projector) will be used to run the program. Students will fill in the provided handouts with the evidence presented to them.

To run through internet: <http://collective.chem.cmu.edu/MixedReception/game/main.html>

Lesson plan link: <http://www.chemcollective.org/mr/>

Assessment

* Hand in worksheets for marking at end of class.
* STSE project due. (Was assigned in lesson 1).

# Lab Safety

* Read the chemical safety information (MSDS)
* Identify the safety equipment
* Dress appropriately for the chemistry lab (no sandals, no contact lenses during labs, etc.)
* Do not pipette by mouth.
* Don’t taste or sniff chemicals
* Don’t casually dispose of chemicals down the drain...
* Don’t eat or drink in the lab.
* Don’t play mad scientist, haphazardly mixing chemicals.
* Inform teacher of any spills or accidents. Clean up immediately.

# Practical/society applications/implications

* Lesson 1
  + Discuss stoichiometry in manufacturing, medicine, geologists (test for CaCO3), space (CO2 scrubbers), air bag inflation, catalytic converters, etc.
  + Real world example with Smores activity.

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* + Assign an STSE project for the stoichiometry unit. Use the curriculum documents in SCH3U D1.1 and D1.2 for topic ideas of how stoichiometry is present in the real world. Students may choose a performance-based assessment from the following website: <http://www.emtech.net/Alternative_Assessment.html>
* Lesson 7
  + Show students the following slideshow of real world uses of stoichiometry: <http://www.wiziq.com/tutorial/73848-Chemistry-Stoichiometry-Real-Life-Stoichiometry>

# Demos

* Lesson 1: Film canister explosion of sodium bicarbonate and water
* Lesson 1: PEOE react KMnO4 with NaHSO3
* Lesson 3: Titration using the Virtual Chem Lab
* Lesson 10: Mixed Reception murder mystery